Global Hydrology Resource Center

Data User Guide

GPM Ground Validation Cloud Physics Lidar (CPL) OLYMPEX

Introduction

The GPM Ground Validation Cloud Physics Lidar (CPL) OLYMPEX dataset consists of extinction profiles, layer optical depth, layer lidar ratio, and aircraft parameter measurements measured by the CPL flown on the NASA ER-2 aircraft during the Global Precipitation Mission (GPM) Olympic Mountains Experiment (OLYMPEX) campaign. The CPL instrument is a multi-wavelength backscatter lidar that provides multi-wavelength measurements of cirrus and aerosols with high temporal and spatial. Data files are available from November 9, 2015 through December 15, 2015 in HDF-5 format with layer information in ASCII text files. Browse imagery files in GIF format contain optical depth and flight path images.

Notice:
Missing and invalid data are shown as -999.0, -9.9, or -9900 depending on variable. Since the data files are collected during each NASA ER-2 flight, there may be missing days between November 9, 2015 and December 15, 2015.

Citation

McGill, Matthew and Dennis Hlavka. 2017. GPM Ground Validation Cloud Physics Lidar (CPL) OLYMPEX [indicate subset used]. Dataset available online from the NASA EOSDIS Global Hydrology Resource Center Distributed Active Archive Center, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/GPMGV/OLYMPEX/CPL/DATA101

Keywords:

NASA, GHRC, OLYMPEX, Washington, NASA ER-2, CPL, Cloud Physics Lidar, Clouds, extinction profiles, layer optical depth, layer lidar ratio, aircraft parameters, aerosols

Campaign

The Global Precipitation Measurement (GPM) mission Ground Validation campaign used a variety of methods for validation of GPM satellite constellation measurements prior to and after launch of the GPM Core Satellite, which launched on February 27, 2014. The instrument validation effort included numerous GPM-specific and joint agency/international external field campaigns, using state of the art cloud and precipitation observational infrastructure (polarimetric radars, profilers, rain gauges, and disdrometers). Surface rainfall was measured by very dense rain gauge and disdrometer networks at various field campaign sites. These field campaigns accounted for the majority of the effort and resources expended by GPM GV. More information about the GPM mission is available at https://pmm.nasa.gov/GPM/.

One of the GPM Ground Validation field campaigns was the Olympic Mountains Experiment (OLYMPEX) which was held in the Pacific Northwest. The goal of OLYMPEX was to validate rain and snow measurements in midlatitude frontal systems as they move from ocean to coast to mountains and to determine how remotely sensed measurements of precipitation by GPM can be applied to a range of hydrologic, weather forecasting, and climate data. The campaign consisted of a wide variety of ground instrumentation, several radars, and airborne instrumentation monitoring oceanic storm systems as they approached and traversed the Peninsula and the Olympic Mountains. The OLYMPEX campaign was part of the development, evaluation, and improvement of GPM remote sensing precipitation algorithms. More information is available from the NASA GPM Ground Validation web site https://pmm.nasa.gov/olympex and the University of Washington OLYMPEX web site http://olympex.atmos.washington.edu/.

Figure 1: OLYMPEX Domain
(Image Source: https://pmm.nasa.gov/OLYMPEX)

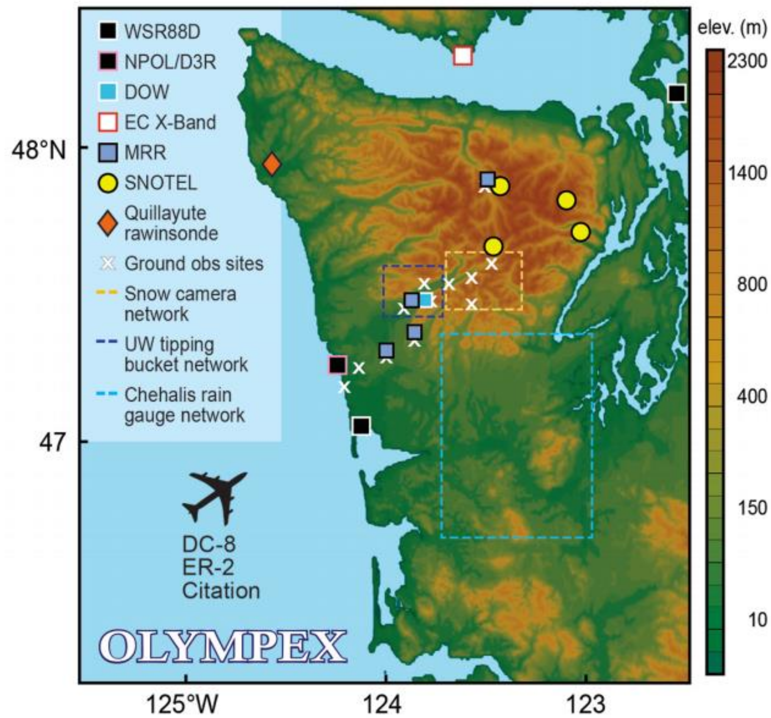

Figure 2: OLYMPEX Field Locations
(Image Source: https://pmm.nasa.gov/OLYMPEX)

Instrument Description

The Cloud Physics Lidar (CPL) instrument is an airborne instrument flown on the NASA ER-2 aircraft as part of the OLYMPEX field campaign. CPL is a multi-wavelength backscatter lidar that provides multi-wavelength measurements of cirrus and aerosols with high temporal and spatial resolution. The CPL operates simultaneously at three wavelengths, 335, 532, and 1064 nm, and has a small field-of-view, which eliminates multiple scattering. The CPL instrument measurements have a vertical resolution of 30 m and a horizontal resolution of 200 m at a typical ER-2 flight altitude of 20 km. The instrument measures the total (aerosol plus Rayleigh) attenuated backscatter as a function of altitude at each wavelength.

The CPL instrument utilizes a high repetition rate, low-pulse energy transmitter and photon-counting detectors. It is designed specifically for three-wavelength operation and maximum receiver efficiency. An off-axis parabola is used for the telescope, allowing 100% of the laser energy to reach the atmosphere. For transmissive cloud/aerosol layers, using optical depth measurements determined from the attenuation of Rayleigh and aerosol scattering and using the integrated backscatter, the extinction-to-backscatter parameter (S-ratio) can be directly derived. This permits an unambiguous analysis of cloud optical depth since only the lidar data is required. Using this derived extinction-to-backscatter ratio, the internal cloud extinction profile can be obtained. More information about the CPL instrument and the data processing approach can be found in McGill et al., 2002, McGill et al., 2003, the NASA Airborne Science Program, McGill et al., 2005, and Vaughan et al., 2010.

Figure 3: CPL instrument before mounted on the NASA ER-2 aircraft
(Image source: NASA Airborne Science Program)

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Data Characteristics

The GPM Ground Validation Cloud Physics Lidar (CPL) OLYMPEX data are available in HDF-5 format files at Level 2 data processing. More information about the NASA data processing levels is available here. Also included are layer location data files in ASCII format. Browse images of ER-2 flight track maps with time stamps for each of the 15 ER-2 flights, and time-height summary curtain images (imgsum) of attenuated backscatter (ATB) per wavelength are also included in GIF format.

Table 1: Data Characteristics

Characteristic	Description
Platform	NASA ER-2 Aircraft
Instrument	Cloud Physics Lidar (CPL)
Projection	n/a
Spatial Coverage	N: 49.634 , S: 34.158, E: -177.775, W: -130.045 (Washington)
Spatial Resolution	Horizontal: 200 m at 20 km flight altitude; Vertical 30 m
Temporal Coverage	November 9, 2015 - December 15, 2015
Temporal Resolution	1 file per flight
Sampling Frequency	1/10 second raw data, 1 second processed data
Parameter	Extinction profiles, layer optical depth, layer lidar ratio, aircraft parameters, aerosol layers, planetary boundary layer
Version	1
Processing Level	2

File Naming Convention

The GPM Ground Validation Cloud Physics Lidar (CPL) OLYMPEX dataset consists of extinction profiles, cloud optical depth, layer lidar ratio, particle size distribution, and aircraft parameter measurements in two HDF-5 files (ATB and OP). Layer location information is provided in associated ASCII files (layers). The browse images are available in GIF format and show ER-2 flight track (map) and time-height cross section image ATB plots for each measurement frequency(imgsum).

Data files: olympex_radex_cpl_[ATB|OP]_hhmmss_YYYYMMDD.hdf5
olympex_radex_cpl_layers_hhmmss_YYYYMMDD.txt
Browse files: olympex_radex_cpl_imgsum_hhhmmss_YYYYMMDD_wave.gif
olympex_radex_cpl_map_hhmmss_YYYYMMDD.gif

Table 2: File naming convention variables

Variable	Description
[ATB|OP]	ATB: Attenuated Backscatter OP: Optical Properties
hh	Two-digit hour in UTC
mm	Two-digit minute in UTC
ss	Two-digit second in UTC
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
.hdf5	Hierarchical Data Format version 5 format
.txt	ASCII format
.gif	Graphics Interchange Format

Data Format and Parameters

The GPM Ground Validation Cloud Physics Lidar (CPL) OLYMPEX dataset consists of HDF-5 and ASCII data files, as well as associated GIF browse files of flight tracks and time-height plots for each channel and depolarization ratio. There are two types of data files: ATB (attenuated backscatter) and OP (Optical Properties). Table 3 describes the data fields within the HDF-5 ATB data files, while Table 4 describes the data fields within the HDF-5 OP data files. Table 5 describes the data fields within the ASCII layer data files.

Table 3: Data Fields in HDF-5 ATB files

Field Name	Description	Data Type	Unit
ATB_1064	Attenuated total backscatter profile for 1064 nm for each record	double	km^{-1} sr^{-1}
ATB_1064_PERP	Attenuated Total Backscatter profile at 1064 nm perpendicular channel	double	km^{-1} sr^{-1}
ATB_355	Attenuated total backscatter profile for 355 nm for each record	double	km^{-1} sr^{-1}
ATB_532	Attenuated total backscatter profile for 532 nm for each record	double	km^{-1} sr^{-1}
Bin_Alt	Altitude for each vertical bin	float	km
Bin_Width	Vertical resolution of the lidar	float	m
Cali_1064	Calibration constant at 1064 nm for each record	double	km^3 / Js^2
Cali_1064_Err	Calibration error at 1064 nm	double	km^3 / Js
Cali_355	Calibration constant at 355 nm for each record	double	km^3 / Js^2
Cali_355_Err	Calibration error at 355 nm	double	km^3 / Js
Cali_532	Calibration constant at 532 nm for each record	double	km^3 / Js^2
Cali_532_Err	Calibration error at 532 nm	double	km^3 / Js
Date	Date for flight	char	-
Dec_JDay	Decimal day of the year to 5 decimal places (second) for current profile	double	UTC
Depol_Ratio	Final depolarization ratio profile for 1064 nm, valid only inside layers	float	-
End_JDay	Decimal Julian day for the end time of the flight	double	UTC
Frame_Top	Top height of CPL reference frame (first bin)	float	km
Gnd_Hgt	Height of Earth's surface detected by lidar missing = -999.0	float	km
Hori_Res	Horizontal resolution of the lidar profiles (typically 1 second or 200 m)	short	s
Hour	Hour of when profile was collected	short	UTC
Latitude	Latitude of profile, decimal degrees, S='-'	float	degrees
Layer_Bot_Alt	Heights of all layer bottoms above mean sea level in profile	float	km
Layer_Top_Alt	Heights of all layer tops above mean sea level in profile	float	km

Layer_Type	Layer type: 0 = missing 1 = PBL 2 = elevated aerosol 3 = cloud 4 = indeterminant	short	-
Longitude	Longitude of profile, decimal degrees, W='-'	float	degrees
MaxLayers	Maximum number of layers allowed per profile	int	-
Minute	Minute of when profile was collected	short	UTC
Mol_Back	Rayleigh backscatter profile of first record, currently used for whole flight for all 3 wavelengths	float	km^{-1} sr^{-1}
NumBins	Number of vertical lidar bins in the optical profiles	int	-
NumChans	Total number of lidar channels, including annulus channels if available, whereas nchan=4 always	short	-
NumLayers	Number of layers detected in current profile	int	-
NumRecs	Number of horizontal records (profiles)	int	-
NumWave	Number of wavelengths in lidar output -- Wavelength (wl) index: 0=355, 1=532, 2=1064nm	int	-
Plane_Alt	Height of the aircraft above mean sea level Missing = -999.0	float	km
Plane_Heading	Plane heading for current profile, clockwise from North	float	degrees
Plane_Pitch	Aircraft pitch, decimal degrees, down='-'	float	degrees
Plane_Roll	Aircraft roll, decimal degrees, left turn = '-'	float	degrees
Pressure	Atmospheric pressure profile of first record, currently used for whole flight	float	hPa
Project	Field project name	char	-
RH	Atmospheric relative humidity profile of first record, currently used for whole flight	float	%
Saturate	Height where detector saturation occurred per channel No saturation = -5000.0	float	km
Second	Second of when profile was collected	short	UTC
Solar_Azimuth_Angle	Solar azimuth angle	float	degrees
Solar_Elevation_Angle	Solar elevation angle	float	degrees
Start_JDay	Decimal Julian day for the start time of the flight	double	UTC
Temperature	Atmospheric temperature profile of first record, currently used for whole flight	float	C

Table 3: Data Fields in HDF-5 OP files

Field Name	Description	Data	Unit

		Type	
Bin_Alt	Altitude for each vertical bin	float	km
Bin_Width	Vertical resolution of the lidar	float	m
Date	Date for this flight	char	-
Dec_JDay	Decimal day of year to 5 decimal places (second) for current profile	double	UTC
Depol_Ratio	Final depolarization ratio profile for 1064 nm, valid only inside layers	float	-
Depol_Ratio_Err	1064 nm Depolarization ratio standard deviation profile	float	-
Direct_OD	Optical depth estimate from transmission loss only per layer per wavelength, not final od of layer -8.8=layer not processed -9.9=invalid	float	-
End_JDay	Decimal Julian day for the end time of the flight	double	UTC
Extinction	Extinction profile per wavelength 0.0=not processed (no layer) -9900=invalid	float	1/km
Extinction_Err	Extinction profile from error profile per wavelength 0.0=not processed (no layer) -9900=invalid	float	1/km
Frame_Top	Top height of CPL reference frame (first bin)	float	km
Gnd_Hgt	Height of Earth's surface detected by lidar, missing = -999.0	float	km
Hori_Res	Horizontal resolution of the lidar profiles (typically 1 second or 200 m)	short	s
Hour	Hour profile was collected	short	UTC
Inver_Type	Type of lidar inversion used -1=missing 0=backward 1=forward	short	-
Latitude	Latitude of profile, decimal degrees, S='-'	float	degrees
Layer_Bot_Alt	Heights of all layer bottoms above mean sea level in profile	float	km
Layer_OD	Final layer optical depth estimate per layer per wavelength -8.8 = layer not processed -9.9=invalid	float	-
Layer_OD_Err	Final layer optical depth from error profile per layer per wavelength -8.8=layer not processed -9.9=invalid	float	-
Layer_Top_Alt	Heights of all layer tops above mean sea level in profile	float	km
Layer_Type	Layer type: 0=missing 1=PBL	short	-

	2=elevated aerosol 3=cloud 4=indeterminate		
Lidar_Ratio	Extinction-to-backscatter ratio used per layer per wavelength -8.8=layer not processed -9.9=invalid	float	sr
Lidar_Ratio_Err	Lidar ratio from error profile per layer per wavelength -8.8=layer not processed -9.9=invalid	float	sr
Longitude	Longitude of profile, decimal degrees, W='-'	float	degrees
LRatio_Source	Source of lidar ratio calculation per layer per wavelength <u>Aerosols:</u> 0=pre-defined default wavelength-dependent equations based on general geographic location and rh 1=educated guess based on recent aerosol history at location (PBL) 2=calculated from available column AOD at location and time 3=pre-calculated from AERONET, CPL, etc. for location and time 4=retrieved directly using technique calculating layer transmission loss 5=future use 6=lowered by a maximum of 5.0sr in order to process down to layer bottom (excludes 4) 7&8=future use 9=missing <u>Clouds:</u> 0=water phase determination based on met temperature profile only, used wavelength dependent equation based on mean layer temperature 1= same as 0 except phase determination based on depolarization ratio and temperature 2=future use 3=1064 nm S ratio calculated from 532 nm optical depth using transmission loss technique 4=retrieved directly using technique calculating layer transmission loss 5=calculated setting layer bottom transmission to reflect extinguished signal 6=lowered by a maximum of 5.0sr in order to process down to layer bottom (excludes 3,4,5) 7&8=future use 9=missing	short	-

MaxLayers	Maximum number of layers allowed per profile	int	-
Minute	Minute profile was collected	short	UTC
Mol_Ext_Prof	Rayleigh extinction profile of first record, currently used for whole flight	float	1/km
NumBins	Number of vertical lidar bins in the optical profiles	int	-
NumChans	Total number of lidar channels, including annulus channels if available, whereas nchan=4 always	short	-
NumLayers	Number of layers detected in current profile	int	-
NumRecs	Number of horizontal records (profiles)	int	-
NumWave	Number of wavelengths in lidar output -- Wavelength (wl) index: 0=355, 1=532, 2=1064 nm	int	-
PGR	Polarization gain ratio - 1064 nm parallel/perpendicular detector relative calibration used	float	fraction
Plane_Alt	Height of the aircraft above mean sea level Missing = -999.0	float	km
Plane_Pitch	Aircraft pitch, decimal degrees, down='-'	float	degrees
Plane_Roll	Aircraft roll, decimal degrees, left turn ='-'	float	degrees
Project	Field project name	char	-
Second	Second profile was collected	short	UTC
Start_JDay	Decimal Julian day for the start time of the flight	double	UTC
T_Loss_Stats	Layer transmission loss technique statistics: 0=passed test 1=no ground return after this final layer 2=no lower layer or ground return 3=clear zone below layer too small 4=clear zone sound-to-noise ratio below minimum 5=transmission^2 of bin below minimum 6=transmission^2 of layer <=0.0 7=1064 nm S-ratio used 532 optical depth	short	-

Table 5: Data Fields in ASCII files

Column	Field Name	Description	Unit
1	Time	Time in the format of hh:mm:ss Where, hh = two-digit hour in UTC mm = two-digit minute in UTC ss = two-digit second in UTC	UTC
2	Lat	ER2 Latitude	Degrees N
3	Lon	ER2 Longitude	Degrees E
4	Alt	ER2 altitude	m
5	Roll	ER2 roll. Observations where the magnitude of the roll exceeds 30 degrees are invalid	degrees
6	N	Number of detected layers of all types	-
7	GH	CPL determined ground height above MSL	m

8-15	LAYER 1-8	(Top Bot D) where, Top = CPL determined layer top above MSL for each layer Bot = CPL determined layer bottom above MSL for each layer D = Layer discriminator indicator 1→ PBL; 2→ Elevated aerosol layer; 3→ cloud for each layer	m

Algorithm

Different layers can have different extinction-to-backscatter ratios (S-ratios), which is the total absorbed and scattered energy divided by the amount of backscattered energy, depending on the layer composition. Because of this, the processing algorithm must be able to discern aerosol types within each layer. The processing algorithm used also calibrates every profile unless clouds are present. More information about the processing algorithm is provided in McGill et al., 2002 and McGill et al., 2003.

The processing algorithm used in the CPL data calibrates every profile collected unless clouds are present. These calibration 1-second averaged profiles are averaged again to a 5-minute resolution, which are then the curve fit to produce a polynomial calibration equation for each wavelength. Also, since the CPL instrument is a nadir-viewing system in the lower stratosphere, the altitude regime used for calibration is in the upper troposphere. More information about the data calibration process can be found in McGill et al., 2003 and Vaughan et al., 2010.

Quality Assessment

Comparison of CPL to CALIPSO data were performed by McGill et al., 2007 showing that CPL and CALIPSO attenuated backscatter agree well, and Cloud layer top determinations from CALIPSO are in good agreement with those determined independently from CPL data.

Software

These data are available in HDF-5 and ASCII formats. No special software is required to view these data; however, Panoply can be used to easily view the HDF-5 data. In addition, the PI has provided IDL read routines for the ATB and OP HDF files. Both routines are available on the GHRC public server.

Known Issues or Missing Data

Missing and invalid data are shown as -999.0, -9.9, or -9900 depending on variable. Since the data files are collected during each NASA ER-2 flight, there may be missing days between November 9, 2015 and December 15, 2015.

References

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Related Data

All data from other instruments collected during the OLYMPEX field campaign are related to this dataset. Other OLYMPEX campaign data can be located using the GHRC HyDRO 2.0 search tool by entering "OLYMPEX" in the search bar.

The CPL instrument was also flown on the Global Hawk in the Hurricane and Severe Storm Sentinel (HS3) field campaign.
Hurricane and Severe Storm Sentinel (HS3) Global Hawk Cloud Physics Lidar (CPL): http://dx.doi.org/10.5067/HS3/CPL/DATA202

Contact Information

To order these data or for further information, please contact:

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Created: October 27, 2017